

# PATENT SPECIFICATION



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The inventor of this invention in the sense of being the actual deviser thereof within the meaning of Section 16 of the Patents Act, 1949, is JEAN HENRI BERTIN, a French Citizen, of 92, Avenue Maurice Barres, Neuilly-sur-Seine, Seine, France.

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## COMPLETE SPECIFICATION

### Improvements relating to Thrust Augmenters for Rocket Motors

We, SOCIETE NATIONALE D'ETUDE ET DE CONSTRUCTION DE MOTEURS D'AVIATION, a French Body Corporate, of 150, Boulevard Haussmann, Paris, France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

- 10 In our Specification No. 730,573, we have described an improvement in jet propulsion units, which consists in converting the continuous jet of gas into a pulsatory jet, and in arranging jet propulsion nozzles in such a way that they become filled with atmospheric air in the intervals between the pulsations, so that the air thus introduced into the propulsion nozzles after the passage of a pulse of gas is pushed out by the next following pulse.

In this way there is obtained an increase in thrust which is considerably greater than in the case of ejectors actuated by a continuous jet so as to draw in atmospheric air. We have been able to establish, in fact, that the efficiency of transformation of energy with pulsatory ejectors approaches unity, being always comprised between 0.5 and 0.8, whilst the efficiency of ejectors operated by a continuous jet rarely attains 0.2 by reason of losses due to friction and mixing.

We have found that the pulsatory dilution, with conversion of the continuous jet into a pulsatory jet, is of particular advantage in the case of rocket motors, especially because of the fact that the flow of gas at high temperature discharged from a rocket possesses a very large specific energy.

According to the present invention there is provided a jet propulsion engine comprising a rocket having a discharge nozzle designed for producing a gaseous jet, characterised by the provision of an ejector tube positioned downstream of said rocket and having an inlet opening facing toward said

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discharge nozzle and adapted to collect the gaseous jet issuing therefrom, the supply of gas to said ejector tube being recurrently interrupted.

The invention is illustrated by way of example in the accompanying drawings in which:

Figs. 1 to 4 show various forms of embodiment of the invention.

In the form of embodiment shown in Fig. 55 1, the transformation to a pulsatory jet of the continuous jet of gas which is usually discharged from a rocket, is obtained by injecting the propellant into the combustion chamber in a pulsatory manner. To this end, the conduits 1 and 2 which convey the combustion-supporting fluid and the fuel to the combustion chamber 3 of the rocket are each provided with a valve 4, 5, the moving members of which are driven in synchronism by a small auxiliary motor of very low power, such as an electric motor, for example, so as to supply the combustion chamber in a periodic manner, the combustion thus taking place in a pulsatory manner. In the drawing, the valves have been shown as of the type with needles 4a, 5a actuated by a rotating cam 4b, 5b. Instead of periodically cutting off the supply of the products, the needles of the valves may be adapted to effect only a periodic reduction of the flow.

The exhaust nozzle 6 of the rocket is followed by an ejector device 7 which is freely open at its front-end so that the atmospheric air may pass freely into this ejector between the pulses of gas.

In this form of embodiment, as in the case of the others which are described below, it is necessary to arrange the ejector 7 suitably so that its efficiency is a maximum.

The inlet orifice of the ejector on the upstream side or, more precisely, the plane which contains that orifice, is separated from the plane of the outlet orifice of the exhaust nozzle of the rocket by an appreciable dis-

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tance which may amount to as much as twice the diameter of the outlet orifice of the discharge nozzle and which is in general in the neighbourhood of half this diameter.

5 The ejector has a convergent-divergent shape with a neck, the cross-sectional area of which is preferably greater than 1.5 times that of the outlet orifice of the discharge nozzle.

10 The divergent section of the ejector is a cone, the apex angle of which is generally less than  $5^\circ$ , but which is in any case less than  $10^\circ$  for frequencies of the pulsatory jet comprised between 50 and 150 per second.

15 For higher frequencies, the divergence may be still further appreciably increased.

Instead of being constant, the divergence may increase towards the downstream side, the increase of divergence being continuous or not, the divergent section being, in the latter case, made up of truncated cones which are more and more divergent towards the downstream side.

A good design of the divergent section is extremely important since it is this section which supports a considerable part of the increase in thrust. Each of the pulses discharged from the rocket opens out into this divergent section, thrusting out the air which it contains and thus giving rise to a pressure on the walls of the said section.

The length of the ejector is preferably less than the distance travelled in one second by sound in the hot gases discharged from the exhaust nozzle, divided by six times the frequency of the pulsations through the discharge nozzle.

As an alternative, the injection of one of the two propellants, combustion-supporting fluid and fuel, may be left continuous, the injection of the other propellant being periodically cut-off or reduced.

If the assembly formed by the combustion chamber 3 and the discharge nozzle 6 is given the form of a resonator tuned to the frequency at which the combustion is cut off or reduced in intensity, the effect of pulsation may be considerably increased.

In the alternative form of embodiment shown in perspective in Fig. 2, the fixed rocket 3, 6, is associated with an assembly of ejector tubes 7 mounted on a common shaft 9 journaled in bearings 10 in such a way that by rotating the block assembly, the ejectors 7 register in succession with the discharge nozzle 6 of the rocket which supplies a continuous flow. The rotation of the assembly of ejectors may be carried out in any way whatever.

A further embodiment consists of a block of fixed ejector tubes 7 and a rotating rocket which supplies the ejector tubes in succession in the course of its rotating movement. It is convenient to provide a number of rockets so that the centre of gravity of the

whole assembly is located on the shaft which carries the rockets, the block of ejector tubes preferably comprising a number of ejectors greater than the number of rockets. The rotation of the block of rockets may be maintained by inclining the axis of the rockets with respect to the shaft. In Fig. 2, there has been shown in dotted lines a rocket symmetrically disposed with respect to the rocket 3, 6 about the shaft 9, which is then supposed to carry both these rockets whilst the block of ejector tubes 7 would be fixed.

In the alternative form of embodiment shown in Fig. 3, the rocket or the rockets are fixed, as are also the ejector or the ejectors, arranged opposite the discharge nozzles of the rockets, and the pulsation is obtained by means of a disc 14 provided with rounded notched portions 15. This disc, which is mounted on a shaft 16 rotatably driven in a continuous manner, has the effect of cutting off and allowing the jets to pass again periodically into the ejector tubes.

It is an advantage to arrange the pulsatory-jet rockets and the ejector tubes within the interior of a cowling which slows down the speed of the atmospheric air and effects, on the upstream side of the ejectors, a transformation of the kinetic energy of this air into pressure energy.

Fig. 4 shows an arrangement of this kind in which one or a number of rockets 3, 6, with a pulsating jet, arranged, for example, in accordance with the description in connection with Fig. 1, and each associated with an ejector tube 7, are arranged, as well as the ejector tubes, within a cowling comprising an air-inlet orifice 18 and a diffuser 19 which slows down the speed of the air. The outlet orifice of the nozzles 6 of the rockets and the inlet orifice of the ejectors 7 are placed in that zone of this cowling at which the speed of the air is reduced to the greatest extent and its static pressure is thus increased. The ejector tubes discharge into the rear portion 20 of the cowling which has a convergent shape, and which opens towards the rear by the discharge orifice 21. A part of the atmospheric air passing through the cowling can circulate around the ejector tubes so as to mix with the discharge from the tubes in the rear chamber 20, the mixture being discharged through the outlet orifice 21 in the form of a propulsive jet of high speed. The rear chamber 20 may also preferably be separated from the upstream portion of the cowling by a partition 23 through which the ejector tubes extend, so that the whole of the air which passes through the cowling must pass also through these ejectors. The latter, in combination with the jets of the rockets, thus each form a kind of pump which delivers air into the rear chamber at a higher pressure. In order to increase still further the energy of the fluid discharged

through the orifice 21, the rear chamber 20 may be used to give an after-burning effect by injection and combustion inside this chamber, by means of burners 22, of a suitable fuel, for example, liquid fuel. In this way, an increase of power is obtained with respect to that of the rocket or rockets arranged inside the cowlings.

It is also possible to regulate the thrust produced by a group of this kind, by placing on the outlet orifice 21 of the cowlings or on the air inlet orifice 18, or on both these orifices, devices for regulating the cross-section of passage of the fluid, these devices being either mechanical (needle-shaped bodies movable axially, shutters or hinged jaws, etc.) or they may be of the aerodynamic type operating by gaseous constriction, produced by deriving fluid from a part of the apparatus at which the static pressure is high, for example, inside the chamber 20 immediately on the downstream side of the partition 23.

What we claim is:—

1. A jet propulsion engine comprising a rocket having a discharge nozzle designed for producing a gaseous jet, characterised by the provision of an ejector tube positioned downstream of said rocket and having an inlet opening facing toward said discharge nozzle and adapted to collect the gaseous jet issuing therefrom, the supply of gas to said ejector tube being recurrently interrupted.

2. Engine as claimed in Claim 1, wherein the discharge nozzle is of circular cross-section and the inlet opening of the ejector tube is spaced downstream of the outlet end of said discharge nozzle by a distance equal at least to the radius of said end.

3. Engine as claimed in Claim 1 or 2, wherein the ejector tube is of convergent-divergent shape with a throat section greater than 1.5 times the outlet area of the discharge nozzle.

4. Engine as claimed in Claim 3, wherein the divergent part of the ejector tube is in the shape of a frustum of a cone whose vertex angle is smaller than  $10^\circ$ .

5. Engine as claimed in Claim 4, wherein the vertex angle is smaller than  $5^\circ$ .

6. Engine as claimed in any of the preceding claims, characterised in that the recurrent interruption of the supply of gas to the ejector tube is produced by means for laterally displacing the rocket relatively to the ejector tube.

tor tube.

7. Engine as claimed in any of Claims 1 to 5, characterised in that the recurrent interruption of the supply of gas to the ejector tube is produced by an obturating device associated with the discharge nozzle of the rocket.

8. Engine as claimed in any of Claims 1 to 5, characterised in that the recurrent interruption of the supply of gas to the ejector tube is produced by means operatively associated with said rocket for producing a recurrent discontinuity in the combustion cycle thereof.

9. Engine as claimed in Claim 8, wherein the recurrent discontinuity producing means comprises a valve in the supply line or lines of the propellants and a control mechanism for periodically opening and closing said valve.

10. Engine as claimed in Claim 9, comprising two valves, one in each supply line, said valves being operated in synchronism to effect simultaneous opening and closing.

11. Engine as claimed in Claims 8, 9 or 10, further comprising a cowlings around the rocket and ejector tube, said cowlings having a ramming intake, an intermediate zone of air at relatively high pressure and a propulsive nozzle, the inlet opening of said ejector tube facing toward said ramming intake and being located in said intermediate zone, said ejector tube having an outlet opening facing toward said propulsive nozzle.

12. Engine as claimed in Claim 11, further comprising fuel injecting means in the cowlings downstream of the ejector tube.

13. Engine as claimed in Claim 11 or 12, further comprising a partition wall across the cowlings, the ejector tube being arranged so as to extend through said partition wall.

14. Engine as claimed in Claim 11, 12 or 13, comprising a plurality of discontinuous combustion rockets inside the cowlings, each rocket being associated with a separate ejector tube.

15. A jet propulsion engine constructed and arranged substantially as herein described with reference to any one of the accompanying drawings.

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